Department of Chemistry and Chemical Biology
Indian Institute of Technology (ISM)
Dhanbad - 826004

LABORATORY MANUAL
FOR

2nd Semester M.Sc. Chemistry
(CYC 513: Organic Chemistry lab - I)

Location: Science Block, 1st Floor, PG laboratory, Department of Chemistry and Chemical Biology

Table of Content

SAFETY

Safety is our biggest concern in this course! You must read and know the section on Safety before starting your first experiment. If you are ever unsure of a procedure, make sure you ask the instructor or the TA.

General Information. A chemistry laboratory is a dangerous place. One must be aware of the dangers and exercise extreme caution at all times. Before beginning work in the laboratory, review the following rules. If you are in violation of any of the following rules, you will be asked to leave the laboratory and will possibly be removed from the course. Eating, drinking, and smoking are strictly forbidden in the laboratory.

Lab Attire. A lab coat is recommended. Protective gloves should be worn whenever the potential exists for contact with toxic chemicals. Shorts and sandals are not safe lab attire, since they provide no protection from splashed or spilled materials. Bare feet are absolutely forbidden in the laboratory. To avoid entanglement with laboratory equipment, necklaces and bracelets should not be worn, and long hair should be tied back.

Chemical Spills. Clean up chemical and water spills immediately. If the spill involves dangerous chemicals, inform the instructor or the TA. Water on the floor can cause slips and falls, and should therefore be cleaned up as soon as possible.

Check Glassware. Small cracks or "star-cracks" can cause glassware to break, explode, or implode. Broken glassware should be turned over to the instructor or TA immediately.

Working with Chemicals. If you are unfamiliar with the properties, safe handling procedures, or disposal requirements of any chemical, consult with your instructor or TA before you attempt to use it. Dispose of all chemical waste in the appropriate containers that are supplied.

Inappropriate Conduct. Disruptive behavior will lead to your immediate dismissal from the laboratory.

Be Prepared. Be familiar with the task at hand Keeping Your Laboratory Notebook

You should have a bound laboratory notebook, with numbered pages, is required for this course (at least 60 pages). Your lab notebook is the primary record of all data and observations generated during the experiment. It is regarded as proof of exactly what you observed, and when the experiments were performed. All calculations (including, for example, gross, tare, and final weights) should be recorded in your notebook - do not make these on scratch paper. All entries should be in ink, and no erasing or white-out should be employed. If an entry is to be disregarded, it should be deleted with a single line drawn through it, such that it can still be read. Record any important observations that you think would help someone else repeat your work. Procedures

should describe what was done and observed, not what you expected to do or observe. The notebooks will be graded in class.

Before you perform each experiment, your laboratory notebook should contain a pre-lab write-up. This should include a title, a purpose, a list of reactants involved with molecular weights, formulas, amounts in grams and moles to be used, and a list of balanced equations including molecular structures that describe the reactions that you will be carrying out. After the pre-lab section, the procedure section in your lab notebook should record what actually happens. Here is where you make your observations about the details of the experiments, including the entries of the weights of materials used and their physical appearance, and all of the data recorded.

Grading

The grading will be based on lab note book/assignments/Lab reports related each experiment*.
The Lab Record Book has to be submitted not later than 7 days from the date of the experiment.

Lab Reports

You should also have a hard bound Lab Record Book, in which the report of the experiment carried out is written. Extreme care shall be taken while preparing this report. There should not be any overwriting, cutting/erasing of the content. The report should be prepared in neat hand-writing. The lab report shall be submitted approximately two weeks after the experiment. The writing must be done only on the ruled page of the fair record. Figures/graphs, if needed, shall be on the blank page. The Lab Report shall contain the following components: Expt. No., Name of the experiment, Objective, Theory/Principle, Procedure, Observations, Calculation, Result/Conclusion. 'Expt. No' shall be on top left corner of the page. 'Name of Expt.' should be in bock letters, centralized and underlined. Each 'subtitles' should be in Block letters and underlined. Procedure shall be reported in passive vice, simple past, past continuous or past participle depending upon the context. The Observations/Readings shall be reported in Tables, the borders of which shall be prepared using scale and pencil. If the results contain values, its units must always be reported. Each student will submit one lab report.

Laboratory Knowledge

The knowledge and preparation of each individual student will be checked in class throughout the course. Students are expected to be able to answer questions on the techniques, procedures, motivations, and expected outcomes of the current experiment.

Essential items

The students while entering lab should have a copy of the instructions sheet, Lab record, Lab note book, A piece of cloth, lab coat, laboratory gloves & goggles etc.

*Includes preparation (pre-lab reading), knowledge of subject matter, cleanliness

Experiment No: 01

Synthesis of Ag (silver) NPs and its potential application towards reduction of 4-nitrophenol

Theory:

Silver particles are nanoparticles in size of 1 nm to 100 nm. They have large surface to bulk ratio. Numerous shapes of nanoparticles can be constructed depending on the application. Commonly used are spherical silver nanoparticles, but octagonal and then sheets are also popular. Their extremely large surface area permits the coordination of silver nanoparticles applicable to the human treatment assessing potential efficacy, toxicity and costs. Now in recent years silver nanoparticles have been gaining attention for catalysis. Silver nanoparticles demonstrate catalytic redox properties for dyes, benzene, and its derivatives and likely other compounds. This heterogeneous catalyst adsorbs the reactant species to the catalytic substrate. The immobilization of the silver nanoparticles on the surface of solid support is a useful technique for fabrication of uniformly distributed Ag NPs as a recyclable heterogeneous catalyst. Herein the catalytic activity of the Ag NPs is confirmed by the reduction of 4-nitrophenol as a model organic compound. After reduction of the 4-notrophenol using Ag NPs, the production of the final product 4-aminophenol is determined by the UV-spectroscopy.

Procedure:

Frist, 0.2 g of polyvinylpyrrolidone (PVP) is dissolved in 20 ml H_2O. Then, 0.03 g $AgNO_3$ is dissolved in 4 ml H_2O and add into the PVP solution as a small portion at a time. After that in a small beaker 0.07 g of $NaBH_4$ is added dropwise to the mixture solution in 10 min. After adding, a dark brown colored colloidal suspension is formed. Take 40 mL of glacial acetic acid in a 100 mL RB flask.

Reduction of 4-notrophenol to 4-aminophenol: In this reduction process, 0.01 g of 4-nitrophenol is dissolved in 20 ml of distilled water. Then, 0.05 g of $NaBH_4$ is added followed by the sonication for 1 min. After that, the reduction is started by 3 ml Ag NPs solution. After 30 on the reduction, the initiation of the reduction of 4-NP is continuously cheeked by the absorbance spectroscopy.

Characterization:

The synthesized Ag NPs, 4-NP, 4-nitrophenolate and formation of 4-aminophenol is characterized by the UV-vis and FTIR spectroscopy.

Yield and Results:

Experiment No: 02 & 03

Block copolymer (*g*-PEG/*p*MMA): derive from poly ethylene glycol (PEG) and methyl methacrylate (MMA) via RAFT polymerization

Theory:

Various methods like free radical polymerization (FRP), ring-opening polymerization (ROP), reversible addition fragmentation chain transfer (RAFT) polymerization, atom transfer radical polymerization (ATRP) were used for the development of functional macromolecules. The conventional free radical polymerization process is usually avoided because of its non-living character that results unwanted homopolymer. Thus, to overcome the disadvantages of free radical polymerization process, controlled radical polymerization (CRP) techniques are used for the fabrication of amphiphilic copolymers. Specially, RAFT is the most preferable technique as it can be used with variety of monomers and reaction conditions. As a result, it provides efficient control over molecular weight and polydispersity (PDI). For RAFT polymerization, xanthate is used as RAFT agent that form less stable radical adduct, which provides control molecular weight with narrow polydispersity. The polymers produced through RAFT are generally halogen-terminated which was used as macroinitiator for chain addition reactions or as precursors of end-functionalized polymers. These modified copolymers are very crucial for potential application in the field of adsorption, biosensors, tissue engineering, and drug delivery.

Synthesis:

Synthesis of macroinitiator: At first, 0.5 g of poly ethylene glycol (PEG) is dispersed in mixture of pyridine (6 mL)/water (10 mL). The solution mixture is heated at 80 °C until become a transparent solution. Then 2-bromo 2-methyl propionyl bromide (2 mL) is added drop wise in cold condition. The reaction is continued at room temperature for 3 h with continuous stirring. The resultant mixture is poured into excess acetone, and precipitated. Afterward, the residue is dried under vacuum at 60 °C for 6 days. The reaction is carried out in inert atmosphere of nitrogen.

Synthesis of g-PEG/pMMA: The controlled synthesis of g-PEG/pMMA is processed through RAFT polymerization. Synthesized macroinitiator is dissolved in 25 mL DMF in a 100 mL 2-necked RB flask. The RB is fixed with stirrer that is kept on an oil bath with constant temperature of 80 °C. Then 0.5 g (0.0031 mol) of potassium ethyl xanthate is added to the reaction mixture and the reaction is continued for 1 h. Then the product is filtered using Whatman 41 filter paper. After that, the xanthate mediated compound is taken in 100 mL 2-nacked RB at 80 °C. Then 0.02 g of AIBN is added to the reaction mixture in N_2 atmosphere. After that, 0.02 mol of MMA is added.

Subsequently the reaction is performed at 80 °C for 2 h in N_2 atmosphere. The reaction temperature is brought down to ambient and precipitated in 100 mL acetone. Finally, the collected product is dissolved in acetone and water mixture (30:70). Afterward, it is heated to 60 °C.

% Conversion is determined using Eq. (1)

% Conversion=Wp/Wm ..... (1)

Wp is the weight of dried graft copolymer and Wm is the initial weight of monomer.

Characterization:

The synthesized copolymer has to characterize using FTIR spectroscopy**.**

Result: Report the % of conversion.

Experiment No: 04

Synthesis of 1,2,3,4-Tetrahydrocarbazole

Theory:

1,2,3,4-tetrahydrocarbazole is a beige crystalline powder having melting point 118-120 °C and soluble in methanol and insoluble in water. It has boiling point 325-330 °C. This compound has attracted considerable attention due to its importance as building blocks for many therapeutically useful materials and the wide range of biological activity of both synthetic and naturally occurring derivatives. The mechanism of synthesis of 1,2,3,4-tetrahydrocarbazole is very much likely to Fischer-Indole synthesis. It involves a complex series of acid catalysed reactions and rearrangement in which the generally key steps are-

1. The condensation of aryl hydrazines with ketones to form aryl hydrazones.
2. Rearrangement of these to form ene-hydrazines.
3. Acid catalyzed sigmatropic [3,3] rearrangement followed by intramolecular displacement of NH_3 to form 1,2,3,4-tetrahydrocarbazole.

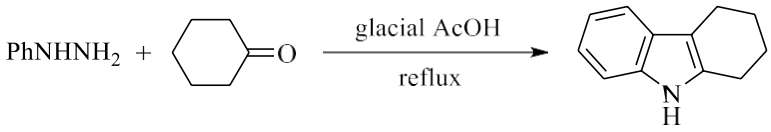
Chemicals required:

1. Glacial acetic acid
2. Phenyl hydrazine
3. Cyclohexanone
4. Ethanol
5. Water
6. 20% Ethyl acetate/Petroleum solution for TLC check.

Apparatus required:

1. 100 mL RB flask
2. Reflux condenser
3. Buchner funnel
4. Filter paper

Reaction:



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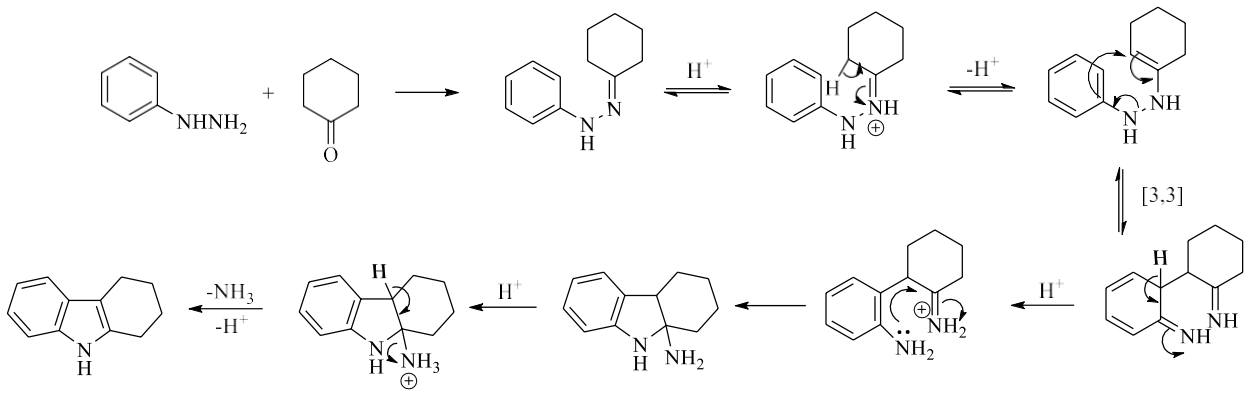


Procedure:

1. Take 40 mL of glacial acetic acid in a 100 mL RB flask.
2. Add 9 mL of Cyclohexanone into glacial acetic acid.
3. Then add 8 mL of Phenyl hydrazine to the above solution.
4. Reflux the mixture of solution for 15 minutes.
5. Cool the mixture until the precipitate appears.
6. Filter and wash with ethanol water (1:1) until the crystal turns to off white.
7. Check the TLC.
8. Report the yield.
9. Record IR and NMR spectroscopy and interpret the result.

Characterization:

- Check TLC with appropriate solvent.
- Record IR Spectroscopy
- Record NMR Spectroscopy

Yield:

Result:

Experiment No: 05

Preparation of Cyclohexanone oxime from Cyclohexanone

Theory:

Oximes are common chemical intermediates. The oxime we are making is used commercially in synthesis of nylon-6. Nylon-6 is a major industrial chemical which is used to make car tire tread and shoe laces. Oximes have also shown to have promise as drugs which reduce the harmful impact from deliberate. In this experiment a cyclohexanone oxime will be formed from cyclohexanone and hydroxylamine. The overall reaction consists as two separate reactions. HCl separates and associates with hydroxylamine molecule forming quaternary nitrogen salt $H_3N^+OH.Cl^-$. First reaction is an acid-base reaction between H_3N^+-OH and Na_2CO_3. Then NH_2OH becomes a very good nucleophile. Here Na_2CO_3 produces NH_2OH from $H_3N^+OH\ Cl^-$.

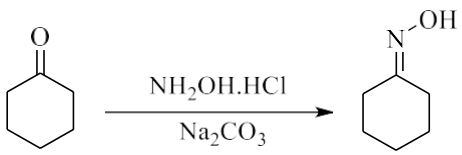
Chemicals required:

1. Cyclohexanone
2. $NH_2OH.HCl$
3. Na_2CO_3
4. Ethyl acetate
5. 10% Ethyl acetate/Petroleum ether solution for TLC.
6. $KMnO_4$ for TLC.
7. Ice bath

Apparatus required:

1. RB flask
2. Beaker
3. Buchner funnel
4. Filter paper

Reaction:



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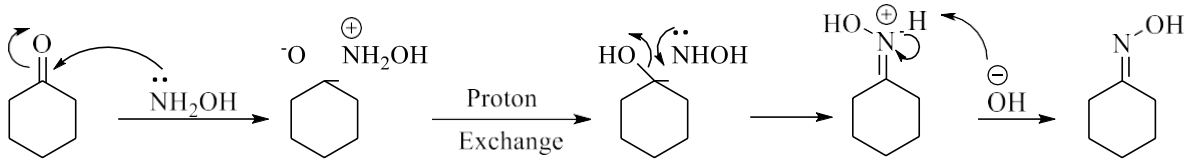


Procedure:

1. Take 10 mL water in a 100 mL RB flask.
2. Then 5.5 ml of cyclohexanone was added to it.
3. Add 4.5 g of $NH_2OH.HCl$ to the above solution.
4. Then add another 10 mL of water with wash the RB.
5. Cool the mixture in ice-water.
6. Add a solution of 3.5 g of sodium carbonate in 20 mL of water slowly to the mixture.
7. After addition, Stir the solution vigorously at room temperature for 20 minutes.
8. Filter and dry it.
9. Check the TLC.
10. Report the yield.
11. Record IR and NMR spectroscopy and interpret the result.

Characterization:

- Check TLC with appropriate solvent.
- Record IR Spectroscopy
- Record NMR Spectroscopy

Yield:

Result:

Experiment No: 06

Preparation of Caprolactam from Oxime by Beckmann Rearrangement

Theory:

The Beckmann rearrangement is an organic reaction used to convert an oxime to an amide under acidic condition. The reaction begins with protonation of the alcohol group forming a better leaving group. The group trans to the leaving group then migrates to the nitrogen resulting a carbocation and attack of H_2O molecule to the carbocationic centre and then tautomerization occurs and amide product is formed. Here also caprolactam has been formed by Beckmann rearrangement from cyclohexane oxime. Majorly it is used to make Nylon-6 filament, fibre and plastics.

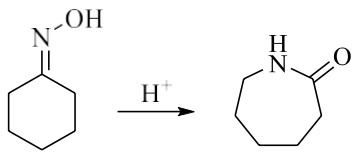
Chemicals required:

1. Cyclohexane oxime
2. Concentrated (85%) H_2SO_4
3. 25% KOH solution
4. DCM
5. Phenolphthalein
6. 10% Ethyl acetate/Petroleum ether.

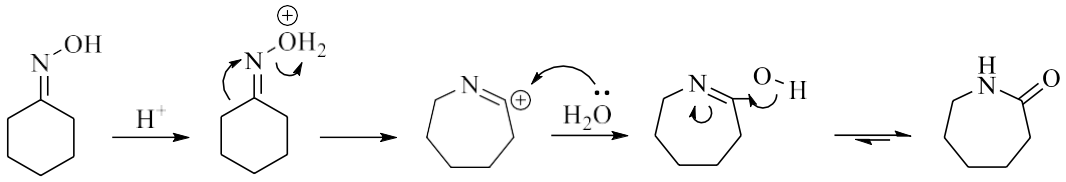
Apparatus required:

1. 500 ml beaker
2. Dropper
3. Buchner funnel
4. Filter paper
5. Separating funnel

Reaction:



Mechanism:



Procedure:

- Prepare the 85% sulfuric acid by adding 50 mL of the concentrated acid cautiously to 10 mL of water.
- Cool the diluted acid in ice-water and place 4 mL of the cold acid in a 250 mL beaker.
- Add 2 g. of the pure oxime and warm the mixture cautiously until effervescence begins, and then at once remove the heat.
- A vigorous reaction occurs and soon completed.
- Cool it in ice-salt bath and add some of crushed ice to the mixture and stir it mechanically whilst slowly adding 25% aqueous potassium hydroxide solution until the mixture is faintly alkaline to phenolphthalein to ensure that the temperature does not rise above 20 °C.
- During this operation a considerable amount of potassium sulphate crystallizes from the mixture.
- Filter the latter at the pump and wash the residual sulphate on the filter with 20 ml. of DCM.
- Run the filtrate into a separating funnel and separate the DCM layer.
- Extract the aqueous layer three times with DCM, using 20 mL on each occasion.
- Dry the united DCM extracts with sodium sulphate and check TLC and concentrate the extract in vacuo. The caprolactam, mp 68-70 °C.

Characterization:

- Check TLC with appropriate solvent.
- Record IR Spectroscopy
- Record NMR Spectroscopy

Yield:

Result:

Experiment No: 07

Synthesis of β-Nitro Styrene

Theory:

Synthesis of β-nitro styrene is commonly done by Henry Reaction of benzaldehyde with nitromethane. It is also referred to as the nitro- aldol reaction where C-C bond formation takes place. The reaction takes place in presence of a base to form beta-nitro alcohol which further undergoes condensation reaction to produce beta-nitro styrene. Henry reaction begins with the deprotonation of nitro alkane on the α-carbon position forming a resonance stabilized anion. This is followed by alkylation of the nitro alkane with the carbonyl containing substrate to form a diastereomeric β-nitro alkoxide. The protonation of the alkoxide by previously protonated base will yield the respective β-nitro alcohol, which undergoes condensation. All of the steps are reversible. Henry reaction is a useful reaction in the field of organic synthetic chemistry due to synthetic utility of its corresponding products, as they can be easily converted to other useful synthetic intermediates. β-nitro styrene is a chemical precursor for silicide's and dyes.

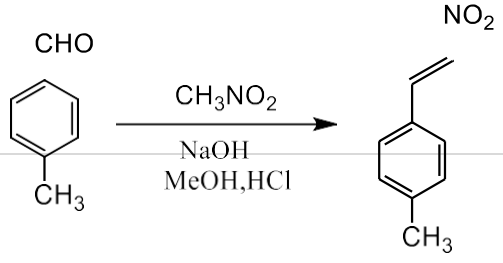
Chemicals required:

1. 4-Chloro benzaldehyde
2. Nitro methane
3. Methanol
4. Distilled water
5. 1 ml NaOH solution
6. Dilute HCl solution
7. 10% ethyl acetate/pet ether solution

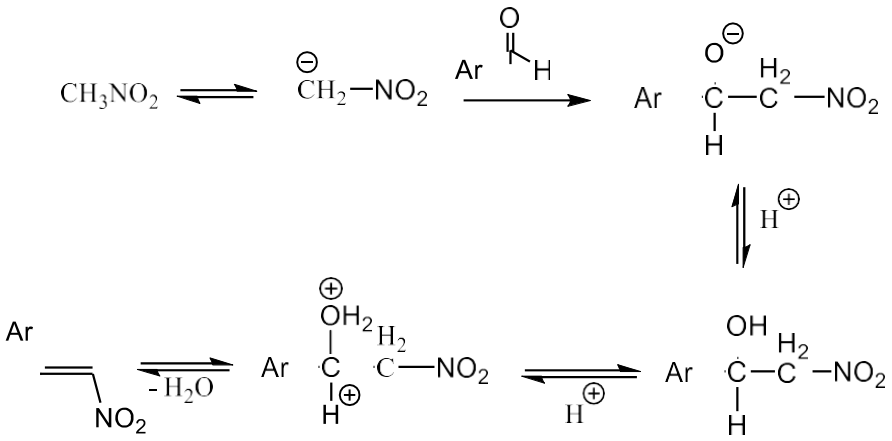
Apparatus required:

1. 500 ml beaker
2. Dropper
3. Buchner funnel
4. Filter paper
5. Separating funnel

Reaction:



Mechanism:



Procedure:

- Take 1 ml of Aromatic aldehyde and 0.5 ml nitromethane in a round bottom flask.
- Add 3 mL of Methanol into the flask.
- Immerse the flask in ice-water bath for 5 min and adds 1 mL of Chilled NaOH solution (by taking 0.42g of NaOH) dropwise with constant swirling, such that the temperature is kept below 10-15 °C.
- The bulky white precipitate forms rapidly during the addition of alkali. The mixture gets so thick that stirring becomes difficult and it may be advice to add 2-3 mL of MeOH.
- After 15 min standing, the pasty mass is converted to a clear solution by the addition of 5 mL of ice water.
- Take 10 mL of chilled Aq. HCl solution (4 mL conc. HCl in 6 mL water) in another flask in ice-water temperature and adds the clear reaction mixture to the acid solution dropwise with constant swirling.
- A pale-yellow crystalline mass separates almost immediately, filter and wash with cold water.
- Check the TLC and report the amount of product.

Characterization:

- Check TLC with appropriate solvent.
- Record IR Spectroscopy
- Record NMR Spectroscopy

Yield and Result:

Experiment No: 08

Preparation of Pyridinium chlorochromate (PCC):

Theory:

Pyridinium Chlorochromate is a yellow orange salt with formula $[C_5H_5NH]^+$ $[CrO_3Cl]^-$. It is a reagent in organic synthesis used for oxidation of alcohol to carbonyls. PCC offers the advantage of selective oxidation of alcohol to carbonyls where many other reagents are less selective. Pyridinium Chlorochromate can be prepared by the dissolution of chromium trioxide (CrO_3) is 6(M) aqueous hydrochloric acid addition of pyridine gives pyridinium Chlorochromate as orange crystals.

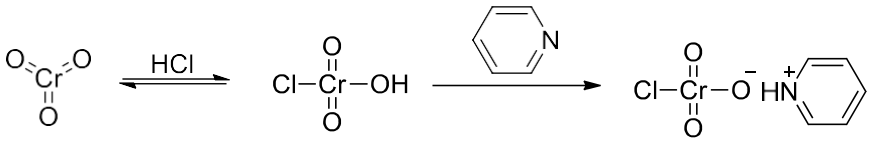
Chemicals required:

1. 6(N) HCl
2. Chromium trioxide
3. Pyridine

Apparatus required:

1. 100 ml beaker
2. Dropper
3. Ice bath
4. Buchner funnel
5. Filter paper

Reaction:



Procedure:

- Take 10 mL 6(N) HCl in a 100 mL beaker and add 5 g of Chromium trioxide into it.
- Then stir the mixture to make homogenous and cool the solution at 0 ℃.
- After that add 4 mL pyridine carefully into the solution to form a yellow orange precipitate.
- Finally filter the precipitate and collect for further characterization.

Yield and Result:

Experiment No: 09

Preparation of Benzaldehyde from Benzyl alcohol using PCC:

Theory:

PCC is a milder version of chromic acid. Essentially what it does to oxidise alcohols from primary alcohols to aldehydes and from secondary alcohol to ketones. PCC will not oxidise aldehydes to carboxylic acids. Here the solvent used is dichloromethane (DCM). Oxidation reactions of this sort are actually a kind of elimination reaction, where we are going from a Carbon-Oxygen single bond to a Carbon-Oxygen double bond. The first step is attack of oxygen on the 'Cr' to form the 'Cr-O' bond. Secondly, a proton on the –OH is transferred to one of the oxygens of the 'Cr' through the intermediary of the pyridinium salt. A Chloride ion is the displaced in a reaction reminiscent of a 1, 2 elimination reaction to form a chromate ester. The 'C=O double bond is formed when a base (Cl-) removes the proton on the carbon adjacent to the oxygen. The electrons from the C-H bond move to form the C-O bond, and in the process, 'O-Cr' bond breaks and Cr(VI) becomes Cr(IV).

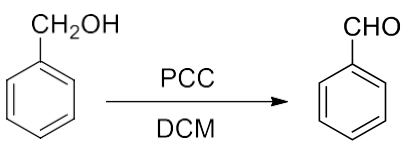
Chemicals required:

1. PCC
2. DCM
3. Benzyl alcohol
4. Celite

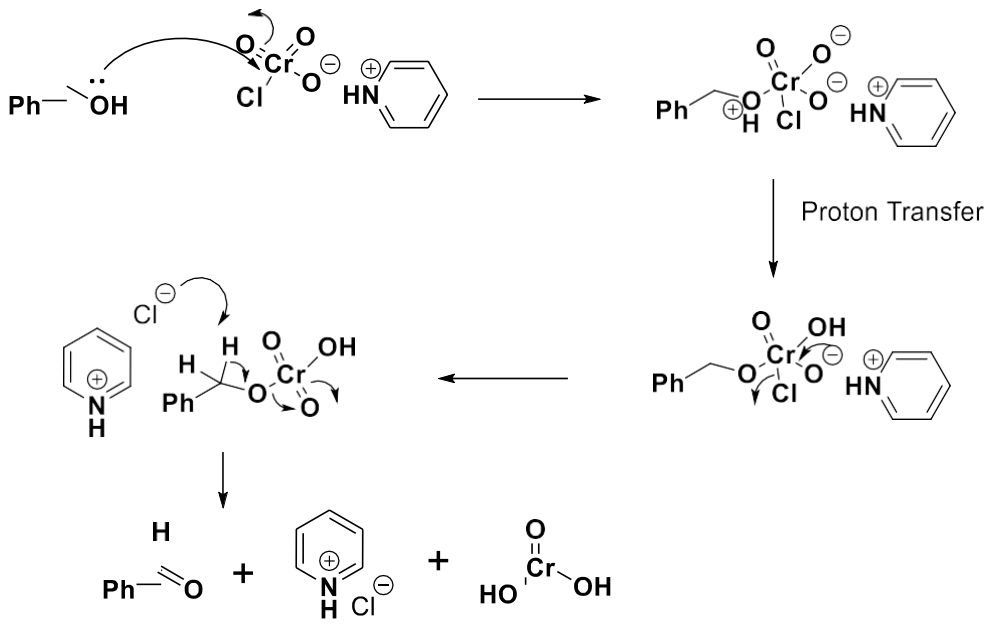
Apparatus required:

1. 100 mL RB flask.
2. Test tube
3. Buchner funnel
4. Filter paper

Reaction:



Mechanism:



Procedure:

- Take 3 g of PCC in a 100 mL RB flask.
- Add 20 mL DCM into it.
- In a separate test tube, dissolve 1 mL of benzyl alcohol in 2 mL of DCM.
- Add this alcoholic mixture at magnetically stirred suspension in the RB flask.
- After 1 h, filter the reaction mixture through celite bed and collect the filtrate.
- Concentrate the filtrate part under vacuo.
- Perform Column Chromatography to elute pure aromatic aldehyde product.

Characterization:

- Record IR Spectroscopy
- Record NMR Spectroscopy

Yield:

Result:

Experiment No: 10

Synthesis of 4-nitrotriphenylamine (NTPA)

Theory:

4-nitrotriphenylamine is Yellow powder having melting point 280 °C and soluble in chloroform and insoluble in water. This compound has considerable importance as it's easily converted into amines that have been using for the formation of many building blocks of useful materials in sensing, transporter, and biological field. The mechanism of synthesis of 4-nitrotriphenylamine is very much likely to addition-elimination reaction in aromatic ring.

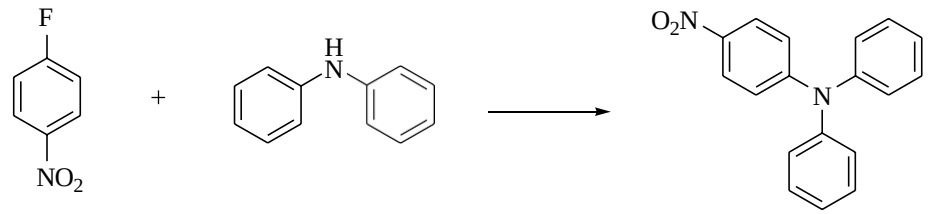
Chemicals required:

1. Diphenylamine
2. p-Fluor nitrobenzene
3. potassium carbonate
4. DMSO
5. Water
6. 15% Ethyl acetate/Petroleum solution for TLC check.

Apparatus required:

1. 100 mL RB flask
2. Reflux condenser
3. Buchner funnel
4. Filter paper
5. TLC plate

Reaction:



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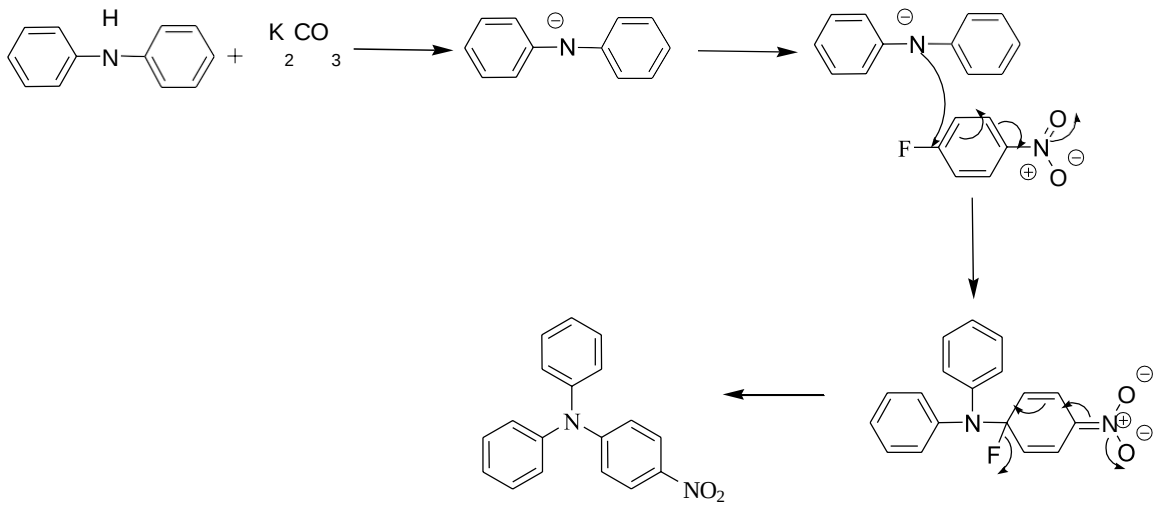

Procedure:

1. Take 10 mL of DMSO in a 100 mL RB flask.
2. Add 1.5 mL of p-Fluor nitrobenzene into DMSO.
3. Then add 2gm of diphenylamine to the above solution.
4. Reflux above reaction mixture after addition 2gm of potassium carbonate at 150℃.
5. After 2hrs cool the reaction mixture and poured it into cold water.
6. Filter the residue and wash with water several times.
7. Check the TLC.
8. Report the yield.
9. Record IR and NMR spectroscopy and interpret the result.

Characterization:

- Check TLC with an appropriate solvent.
- Record IR Spectroscopy
- Record NMR Spectroscopy

Yield:

Result: